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**“Plasma Parameters from Coordinated  
SERTS and Yohkoh Observations”**

covering the period 30 June 1995 — 29 June 1996

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## PROJECT SUMMARY

The purpose of this investigation was to carry out a joint analysis of plasma parameter measurements obtained from Yohkoh Soft X-Ray Telescope (SXT) broadband filter data, and from high-resolution EUV spectral line data and spectroheliograms acquired during the 17 August 1993 flight of Goddard Space Flight Center's Solar EUV Rocket Telescope and Spectrograph (SERTS). We observed two solar active regions (NOAA regions 7563 and 7565), quiet-sun areas, and a coronal hole region simultaneously with SERTS and with SXT. SERTS provided spatially resolved active region and quiet-sun slit spectra in the 280 to 420 Å wavelength range, and images in the lines of He II  $\lambda$  303.8, Mg IX  $\lambda$  368.1, Fe XV  $\lambda$  284.1, and Fe XVI  $\lambda\lambda$  335.4 and 360.8. SXT provided images through multiple broadband filters in both the full- and the partial-frame imaging modes.

The SERTS images in Fe XV ( $\log T_{max}=6.33$ ) and Fe XVI ( $\log T_{max}=6.43$ ) exhibit remarkable morphological similarity to the SXT images. Whereas the Fe XV and XVI images outline the loop structures seen with SXT, the cooler He II ( $\log T_{max}=4.67$ ) and Mg IX ( $\log T_{max}=5.98$ ) images outline loop footpoints as well as other structures not necessarily associated with the hot loops.

From the spatially resolved slit spectra, we obtained emission line profiles for lines of Fe X (5.98) through Fe XVI, He II, Mg IX, Si XI (6.20), and Ni XVIII (6.52) for each spatial position. The spatial variations of the line intensities show that active region 7563 systematically narrows when viewed with successively hotter lines, and appears narrowest in the broad band soft X-ray emission. The active region width diminishes linearly with  $\log T_{max}$ , yielding an extrapolated effective  $\log T_{max}$  of  $6.51 \pm 0.01$  for the X-ray emission.

Active region and quiet-sun one-dimensional temperature scans were derived from intensity ratios of spatially resolved SERTS slit spectral lines, and from coregistered SXT filter ratios. The highest plasma temperatures were measured in the most intense, central core of region 7563. The temperatures derived from Fe XVI  $\lambda$  335.4/Fe XV  $\lambda$  284.1 and Fe XVI  $\lambda$  335.4/Fe XIV  $\lambda$  334.2 vary significantly (based upon the measurement uncertainties) but not greatly (factors  $< 1.5$ ) across the slit. The average  $\log T$  values derived from the above two ratios for region 7563 are  $6.39 \pm 0.04$  and  $6.32 \pm 0.02$ , respectively. Somewhat larger (factor  $\sim 2$ ) systematic variations were obtained from all available SXT filter ratios. The average active region  $\log T$  values derived from the SXT AlMgMn/thin Al, thick Al/thin Al, and thick Al/AlMgMn filter ratios are  $6.33 \pm 0.03$ ,  $6.45 \pm 0.02$ , and  $6.49 \pm 0.03$ , respectively. The temperatures derived from Fe XIII  $\lambda$  348.2/Fe XII  $\lambda$  352.1 and Fe XII  $\lambda$  352.1/Fe X  $\lambda$  345.7 exhibit no systematic variations across the slit; the corresponding average values are  $6.14 \pm 0.04$  and  $6.07 \pm 0.02$ .

Active region and quiet-sun one-dimensional density scans were derived from intensity ratios of spatially resolved SERTS slit spectral lines of Fe XII, XIII, and XIV. Although the derived densities do not vary significantly across either slit location, the derived active region densities are  $\sim 2$  times the quiet-sun densities. This density difference is adequate to explain the factor  $\sim 4$  intensity difference in Fe XII and Fe XIII between the active and quiet areas, but it is not adequate to explain the factor  $\sim 8$  intensity difference in Fe XIV between the active and quiet areas. We attribute the latter to greater active region path lengths and/or volume filling factors.

Statistically significant Doppler shifts are not detected in region 7563 with any of the EUV lines. However, significant blueshifts of  $25 \pm 5$  km s $^{-1}$  are detected in the region 7565 sunspot with Fe XII  $\lambda$  352.1, Fe XIII  $\lambda$  348.2, and Si XI  $\lambda$  303.3.

# 1 Introduction

The purpose of this investigation was to carry out a joint analysis of plasma parameter measurements obtained from Yohkoh Soft X-ray Telescope (SXT) broadband filter data, and from high-resolution EUV spectral line data and spectroheliograms acquired during the 17 August 1993 flight of Goddard Space Flight Center's Solar EUV Rocket Telescope and Spectrograph (SERTS). The jointly observed features include a coronal hole, quiet-Sun loops, plage, a sunspot, and complex magnetic structures in two active regions and the region connecting them. Individually, the SXT and SERTS data sets represent the state of the art of measurements of their kind. Together, they provide a unique set of simultaneous, complementary information on the physical conditions of the multithermal plasma in coronal structures – information which is absolutely essential for realistic models of those structures and the physics which governs them.

# 2 Conclusions

I have successfully completed my portion of this project, and summarize my primary conclusions below.

## 2.1 Soft X-Ray and EUV Image Morphology

The SERTS images in Fe XV and XVI exhibit remarkable morphological similarity to the *Yohkoh* SXT images: the EUV emission from these hot ions generally outlines the same loop structures seen in soft X-rays. EUV emission from the cooler He II and Mg IX ions, although closely associated with the soft X-ray structures, tends to delineate loop footpoints as well as structures which are not necessarily associated with the hot loops.

## 2.2 Spectral Scans

From the spatially resolved SERTS slit spectra, we obtained one-dimensional intensity scans for emission lines of Fe X – XVI, He II, Mg IX, Si XI, and Ni XVIII. These scans show that active region 7563 systematically narrows as it is viewed with successively hotter lines; the region appears narrowest in the broad band soft X-ray emission. The active region width (full width at half maximum intensity) diminishes linearly with  $\log T_{max}$ . The linear fit to the EUV line intensities yields an extrapolated effective  $\log T_{max}$  of  $6.51 \pm 0.01$  for the soft X-ray emission.

## 2.3 Temperature Diagnostics

Active region and quiet-sun one-dimensional temperature scans were derived from intensity ratios of spatially resolved slit spectral lines, and from coregistered SXT filter ratios. The highest plasma temperatures were measured in the most intense, central core of region 7563. The temperatures

derived from Fe XVI  $\lambda$  335.4/Fe XV  $\lambda$  284.1 and Fe XVI  $\lambda$  335.4/Fe XIV  $\lambda$  334.2 exhibit significant (based upon the measurement uncertainties) but not substantial (factors  $< 1.5$ ) variations across the SERTS slit in both pointing positions; in particular, they systematically increase toward the interior of region 7563 and in the sunspot penumbra of region 7565. Somewhat larger (factor  $\sim 2$ ) systematic variations were obtained from all available SXT filter ratios. The Fe XIII  $\lambda$  348.2/Fe XII  $\lambda$  352.1 and Fe XII  $\lambda$  352.1/Fe X  $\lambda$  345.7 ratios show considerably more temperature scatter, but the systematic trends seen in the hotter ion ratios are absent; these line ratios yield the same temperatures both inside and outside the active regions. Temperatures derived from the SXT filter ratios and from the SERTS line intensity ratios, although not equal, are mutually consistent.

## 2.4 Density Diagnostics

The electron density does not vary significantly across the SERTS slit in either pointing position, despite the fact that the emission line intensities themselves vary substantially across the same areas on the Sun. For density sensitive line intensity ratios of Fe XII, XIII, and XIV, the active region densities are  $\sim 2$  times the quiet Sun densities. For the Fe XII and XIII lines, this density enhancement is sufficient to explain the observed active region over quiet Sun intensity enhancement. For the Fe XIV lines, the active region over quiet-sun intensity enhancement can only be explained by an additional enhancement in the product of the filling factor and the path length:  $[f\Delta\ell]_{ar} = 3[f\Delta\ell]_{qs}$ .

## 2.5 EUV Doppler Shifts

None of the SERTS emission lines exhibited significant Doppler shifts in the central portion of region 7563. All of the EUV lines examined exhibited Doppler shifts at various locations throughout the quiet-sun. Fe XII, Fe XIII, and Si XI were the only ions to show Doppler shifts in the sunspot in region 7565; in each case the flow is upward.

# 3 Publications and Presentations

The paper “The Structure and Properties of Solar Active Regions and Quiet-Sun Areas Observed in Soft X-Rays with Yohkoh/SXT, and in the Extreme Ultraviolet with SERTS” (J.W. Brosius, J.M. Davila, R.J. Thomas, J.L.R. Saba, H. Hara, & B.C. Monsignori-Fossi) was submitted for publication in *The Astrophysical Journal*. As of this writing, I have not yet heard from the referee.

Results of work completed during this project were presented at the 1996 Spring Meeting of the American Geophysical Union in Baltimore, MD, and at the AAS/SPD meeting in Madison, WI. Both presentations were titled “The Structure and Properties of Solar Active Regions and Quiet Sun Areas Observed With SERTS and Yohkoh,” by J. W. Brosius, J. M. Davila, R. J. Thomas, and H. Hara. The abstract for the AGU meeting can be found in *Eos* (Supplement), vol. 77, p. s218 (1996). The abstract for the AAS/SPD meeting can be found in *BAAS*, vol. 28, p. 880 (1996).

## 4 Discussion

The success of this project can be measured by more than the scientific output outlined above. In addition to the science results, we have established excellent working relationships with our Japanese collaborators. In particular, Dr. Hirohisa Hara has shown enthusiasm for future collaborative investigations.

Dr. Brunella C. Monsignori-Fossi passed away in January 1996, ending the fruitful collaboration that I had with her for the last several years. Fortunately, her longtime colleague, Dr. Massimo Landini, volunteered to maintain our collaboration. This will be important for the analysis of data obtained during the 1995 SERTS flight, which will be done under separate NASA funding.

More science results will be coming out of this project since the Project Principal Investigator, Dr. Julia L. R. Saba, has not yet completed her part of the investigation (owing largely to the fact that her NASA contract under this proposal was not set in place until nearly 6 months after my NASA-Hughes contract). She continues working despite new commitments to SOHO/MDI. I expect to continue interacting with Dr. Saba as she finishes her part of the project, but at a very low level since my contract on this project has expired.

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